Integrated GPS/Loran Prototypes for Aviation Applications

by

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A follow-up to:

Loran-C As A Secondary Navaid To Complement GPS

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Robert N. Snow, Boeing Company
G. Linn Roth, Locus Inc.
Mitchell J. Narins, Federal Aviation Administration

May 1, 2002

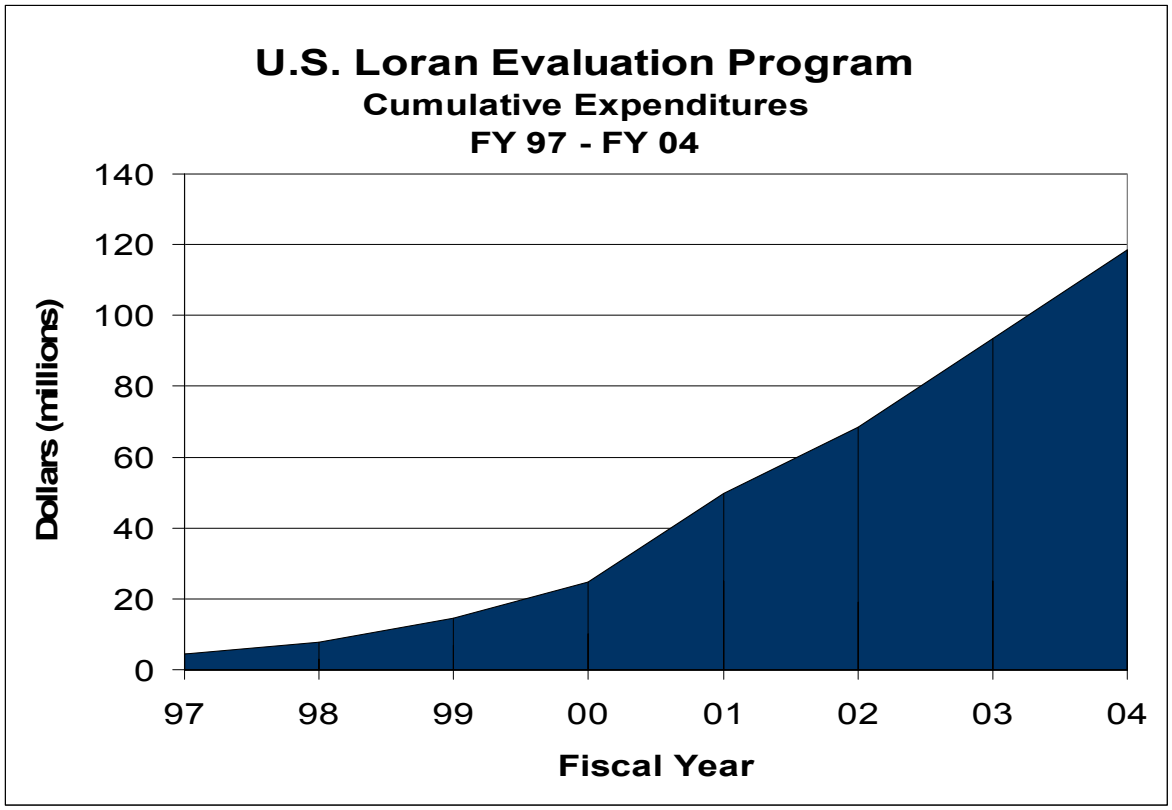
Outline

- Loran - Interest, Modernization, Future
- Review of Rockwell/Locus GPS/Loran Integration Program
- Review of FreeFlight/Locus GPS/Loran Integration Program
- Summary

Loran - Interest

- DOT's Volpe study on GPS vulnerabilities, 9/11, and other events spurred interest in independent backup systems for both navigation and timing, i.e. critical infrastructure areas
- Loran is the only other multimodal radionavigation system, and it could, through modernization and changes in operational procedures, provide much better performance than is currently available
- USCG is interested in whether Loran can support harbor entrance and approach (HEA) and has performed studies to determine if an enhanced Loran system can meet HEA standards
- FAA is interested in whether Loran can support non-precision approach (NPA) and has performed studies to determine if an enhanced Loran system can meet NPA required navigation performance (RNP) requirements for accuracy, availability, integrity and continuity
- Other multimodal interest in Loran exists (e.g. numerous time/frequency applications)

Loran - Modernization



- During the technical evaluations, Congress has continued Loran support, providing ~$120M from 1997 to 2004 to modernize Loran infrastructure; more support in FY05
- Loran infrastructure upgrade well underway toward an enhanced or “e-Loran” system

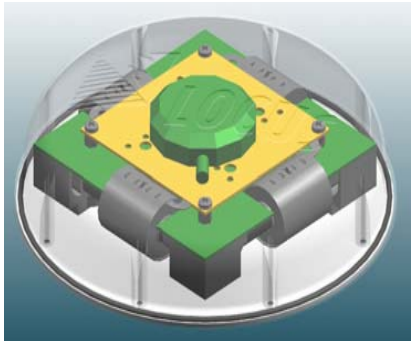
Loran - Modernization

- An E-Loran transmitter system:
  - 3 Agilent 5071A Cs at each transmitter, likely forming largest distributed primary clock system in the world
  - solid state transmitters with state-of-the-art time and frequency clock measurement and control equipment (TFE), UPS's, etc.
  - TFE uses GPS data to steer ensemble averaged 5071A's and to provide ~15 ns UTC (USNO) recovery at each transmitter
  - transmitters will use time-of-transmission control ala GPS
  - new 9th pulse will be added that:
    - Provides differential Loran corrections, UTC, leap seconds, station identification, etc.
    - Means users only require strongest signal to get absolute time
  - TFE has potential to utilize all USCG 5071A's to compute single timescale

Loran - Modernization

- An E-Loran receiver:
  - all-in-view (i.e. 40 station tracking)
  - linear, DSP-based
  - adaptive filtering, cross rate blanking, etc.
  - demodulation of 9th pulse

- E-Loran antennas:
  - H-field - small (16x16x6 cm)
  - E-field - short (46 cm)
  - Combined GPS/H-field antennas

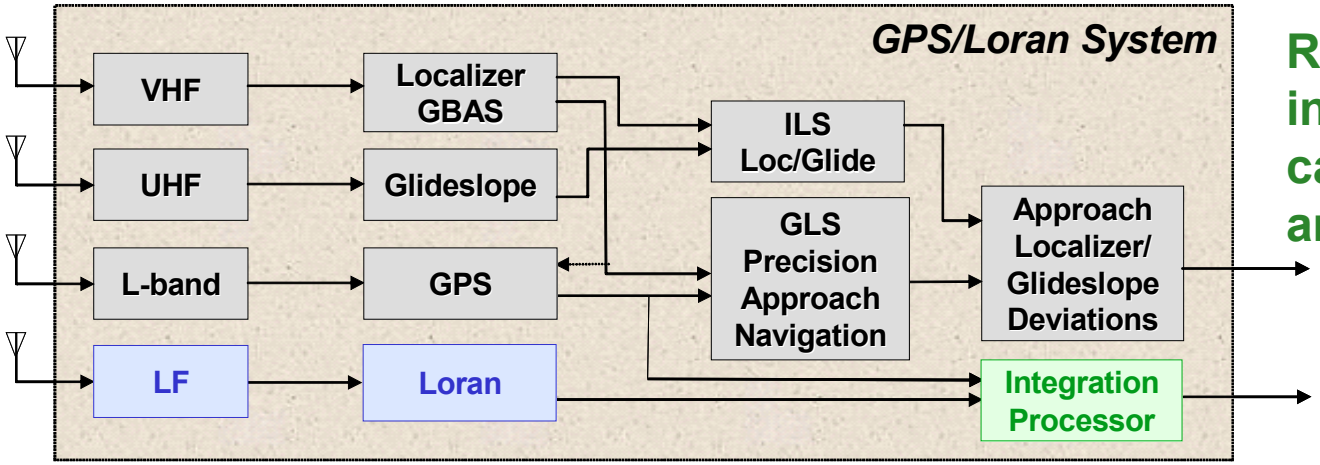


Combined GPS/H-field Antenna

Loran - Future

- To augment FAA/USCG technical evaluations, the Volpe Center also performed Loran benefit/cost study
- Results of FAA/USCG technical evaluations and results of Volpe benefit/cost study were turned over to DOT on March 31
- DOT has stated they are planning to issue long-term Loran policy statement on June 30, 2004

Rockwell/Locus GPS/Loran Integration Program

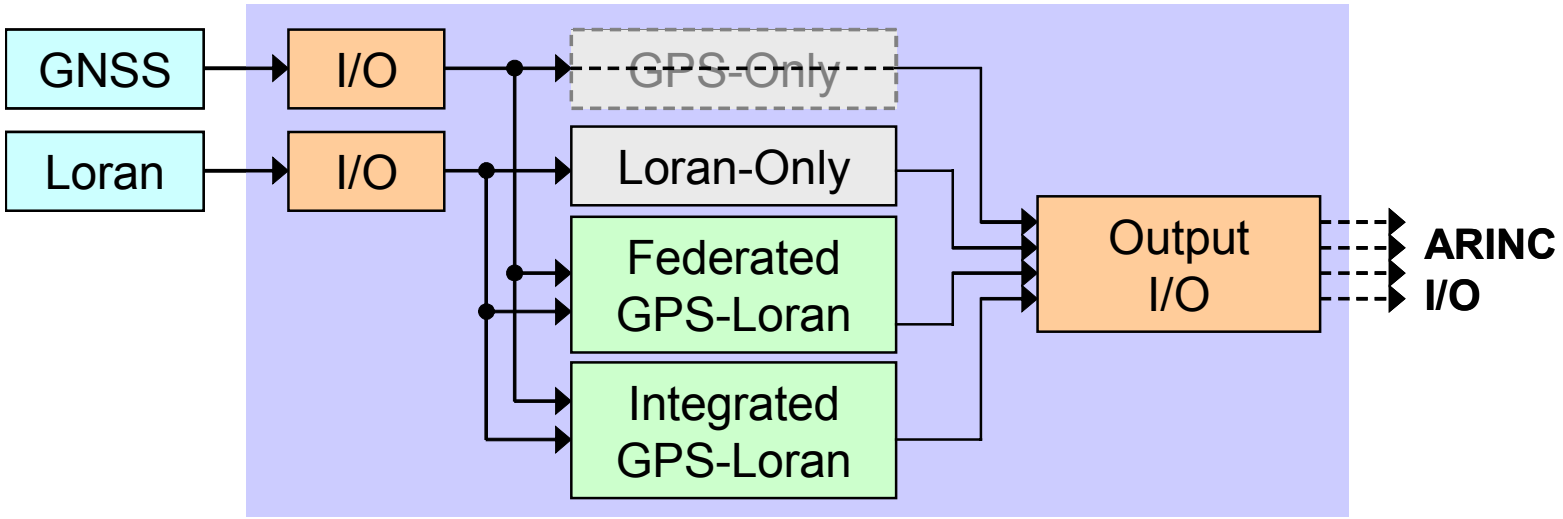


Rockwell Collins integration processor card combines GPS and Loran data

Locus Loran receiver card is installed on the MMR door in place of the MLS

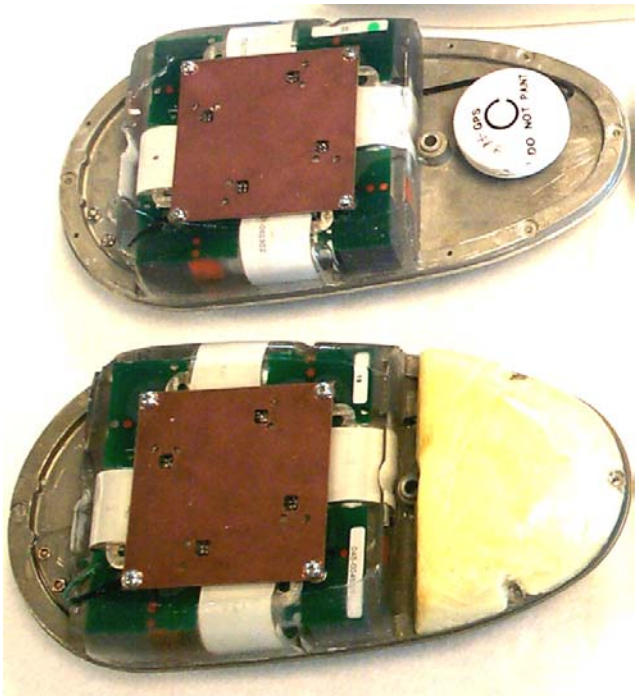
Rockwell multimode receiver (MMR) is prototype platform (see GPS World, May, 2003)

Rockwell/Locus GPS/Loran Integration Program



- GPS/Loran integration processor (GLIP) forms and manages multiple solutions of position and integrity, including:
  - "GPS-only" passes through GNSS solution
  - "Loran-only" mimics Locus' solution
  - "Federated" GPS/Loran processes GPS and Loran but maintains independence - adapted from Rockwell RAIM-FDE design
  - "Integrated" GPS/Loran determines Loran ASF corrections using GPS

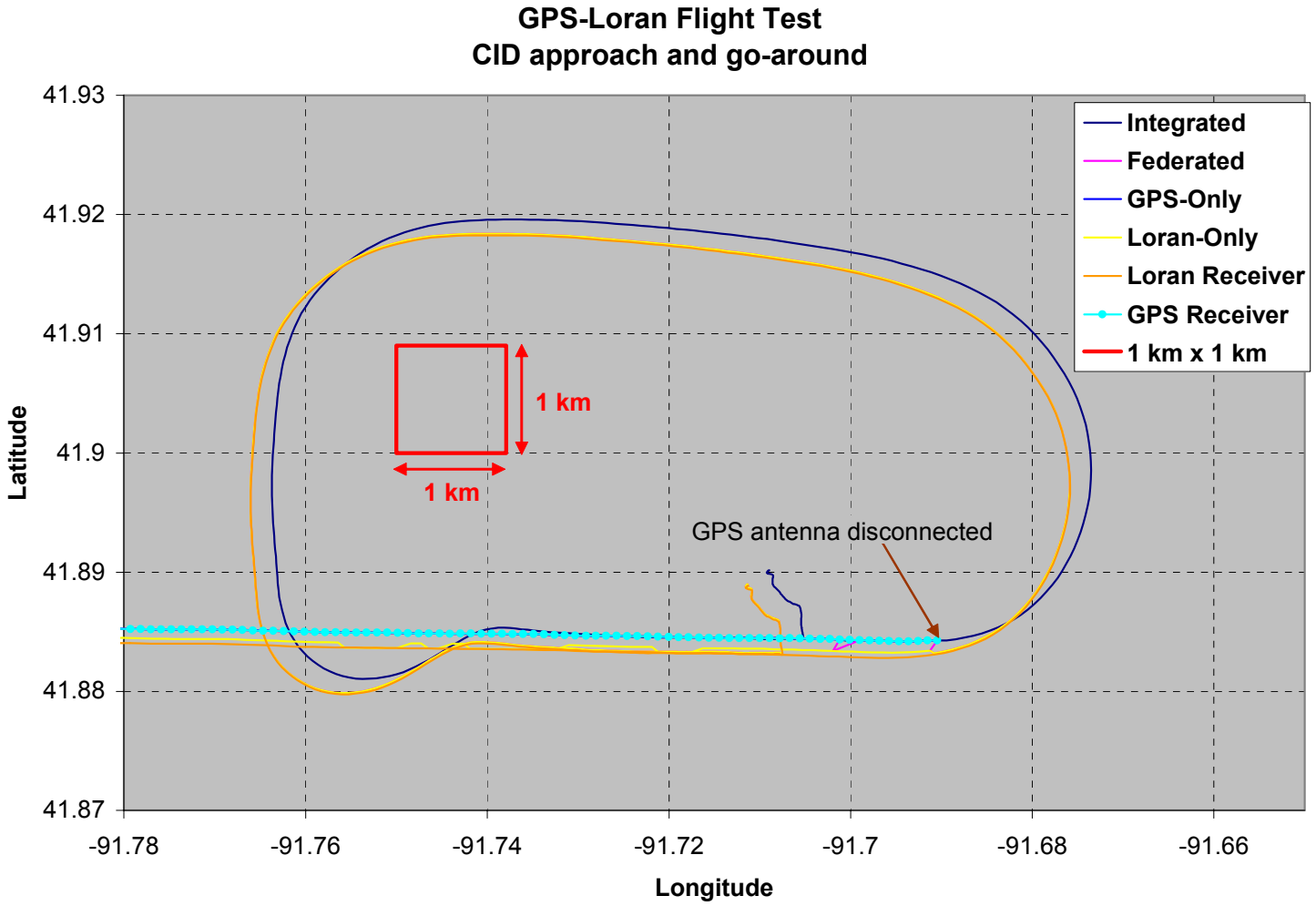
Rockwell/Locus GPS/Loran Integration Program



Integrated GPS/Loran antenna in ADF radome

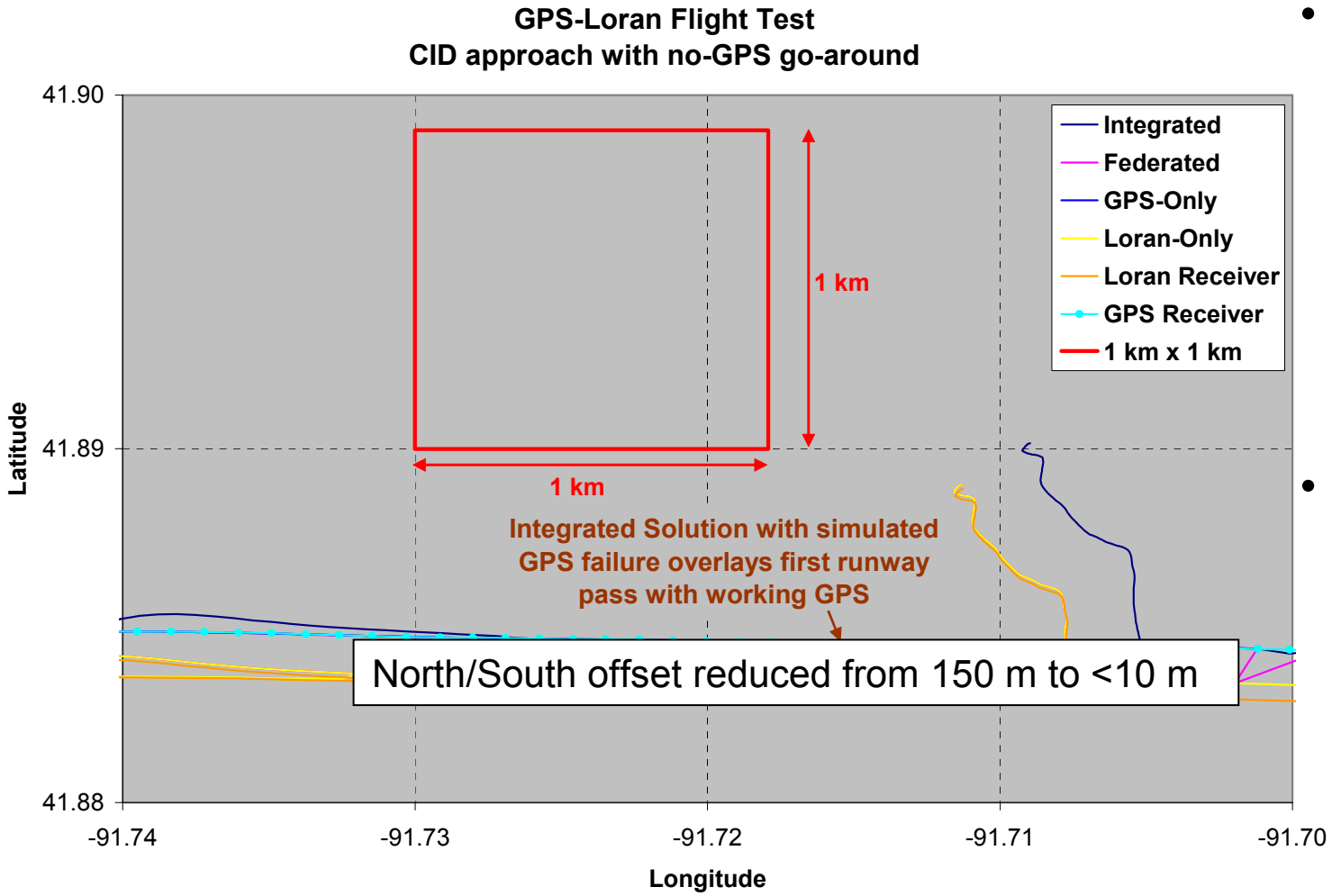
Initial flight tests performed on Ohio University's Avionics Engineering Center (AEC) King Air, C-90SE twin turboprop

Rockwell/Locus GPS/Loran Integration Program - Initial Tests



- After low pass of the Cedar Rapids runway the GPS antenna was disconnected to simulate a GPS failure
- Thereafter, the "coasting" Integrated solution overlays first runway pass with GPS

Rockwell/Locus GPS/Loran Integration Program - Initial Tests



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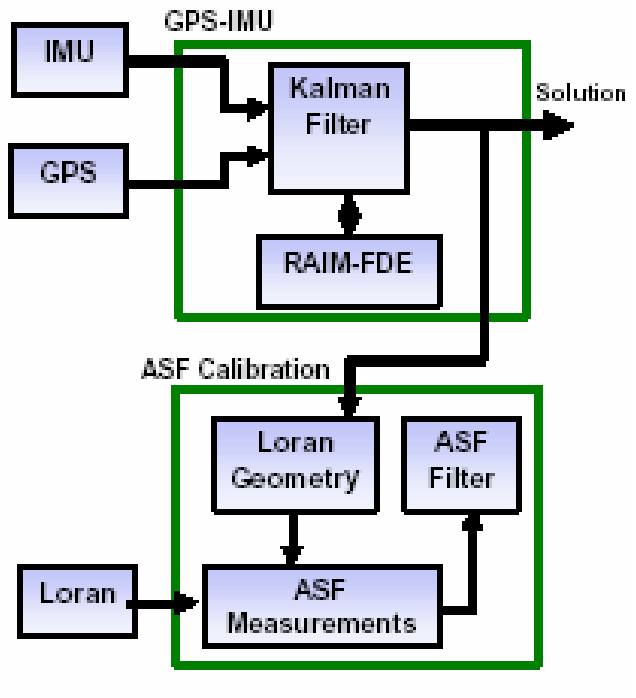
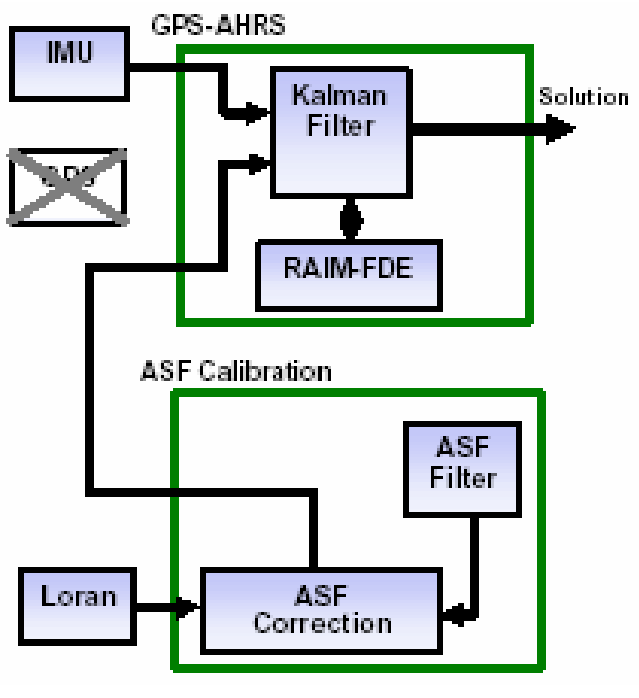
Continuing Work

- Rockwell Collins is evaluating performance enhancements possible with inertial aiding of Loran using a low-cost MEMS AHRS



GPS-IMU-Loran System Diagram when GPS is available



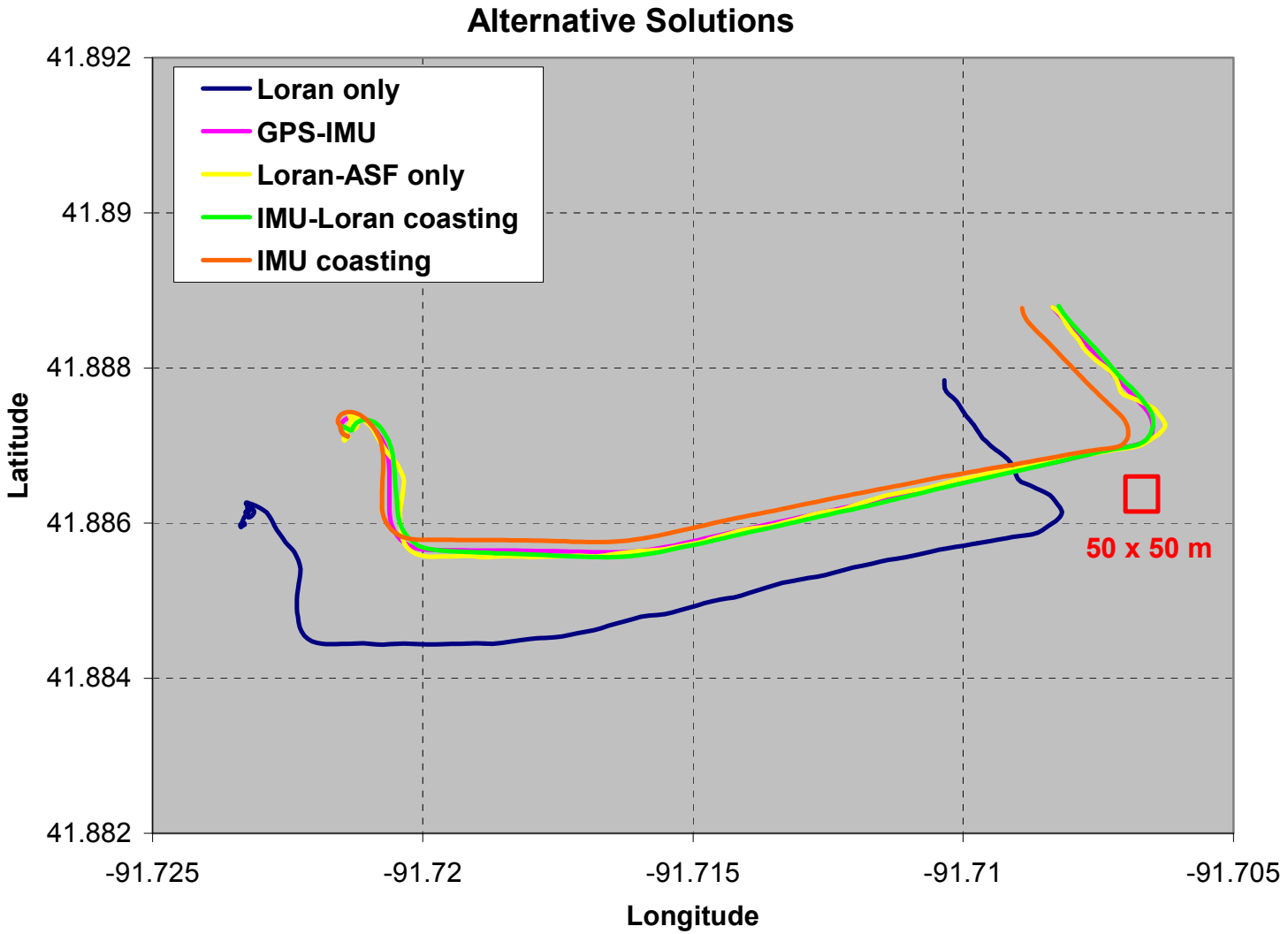
GPS-IMU-Loran System Diagram when GPS is not available

From Anderson and Doty, ION NTM, January, 2004

Continuing Work
GPS-IMU-Loran Integration

- **AHC-3000A AHRS modified to add IMU outputs**

Taxi Data Evaluation
GPS-IMU-Loran Integration



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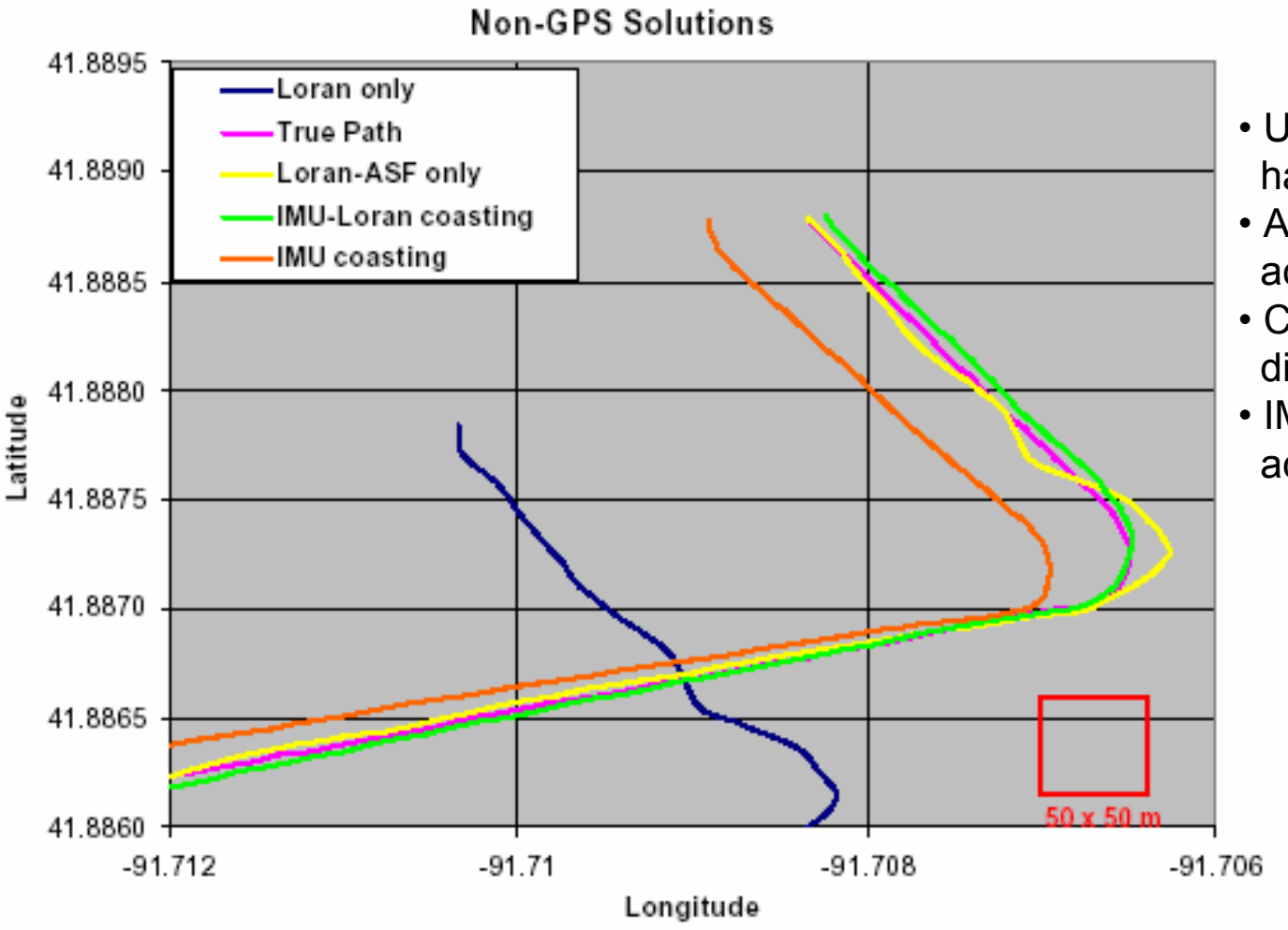


- Uncorrected Loran has large bias
- ASF-corrected Loran is accurate but noisy
- Coasting IMU has diverging solution
- IMU-Loran has accuracy and low noise

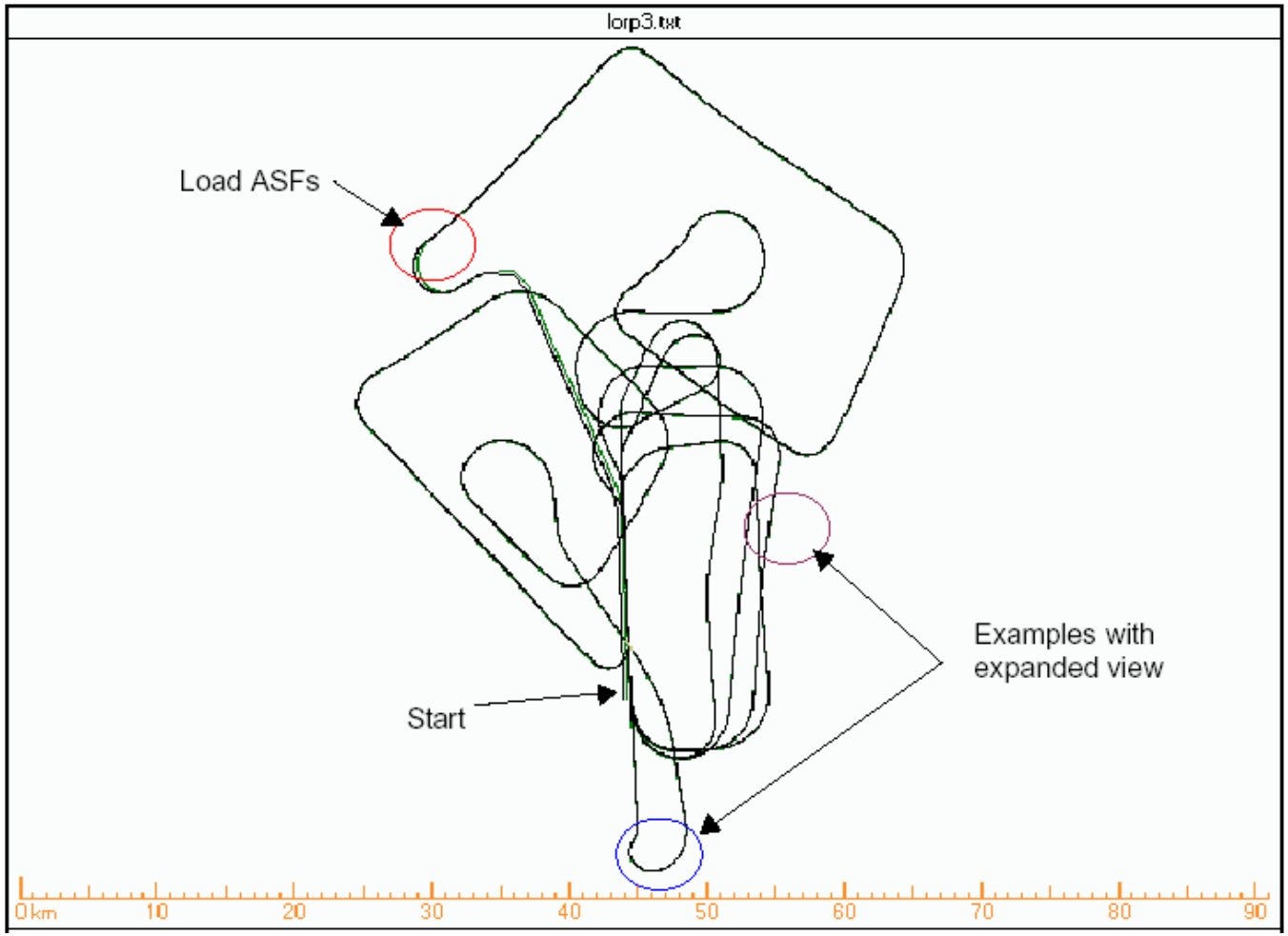
From Anderson and Doty, ION NTM, January, 2004

FreeFlight/Locus GPS/Loran Integration Program

- Began with 2 unit prototype of FFS Model 2101 Approach Plus GPS/WAAS receiver and SatMate 1030 Loran receiver
- No significant integration of GPS/Loran data and electronics
- Also combined GPS/Loran antennas in ADF radome for flight tests

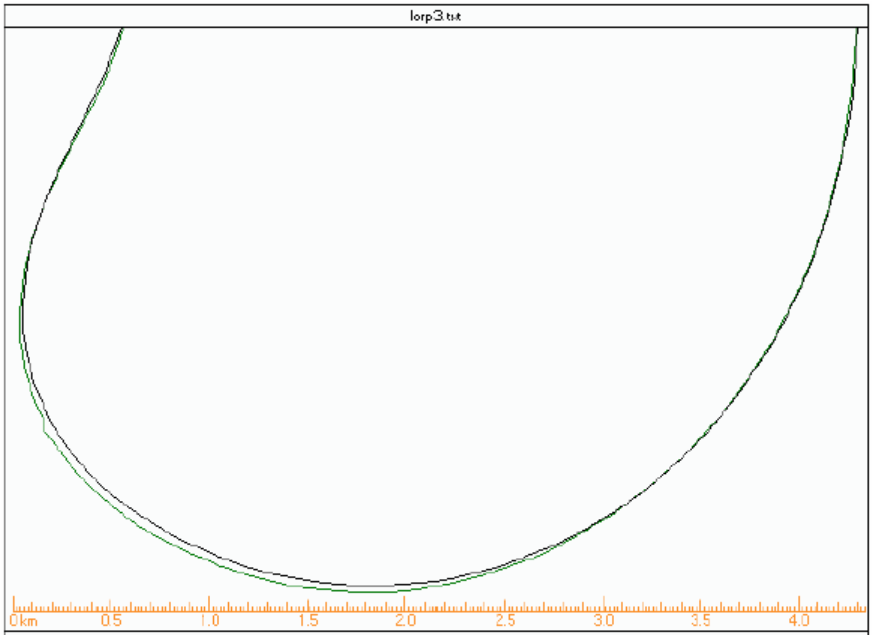
First prototype included course deviation indicator (CDI)

FreeFlight/Locus GPS/Loran Integration Program - Initial Flight Tests

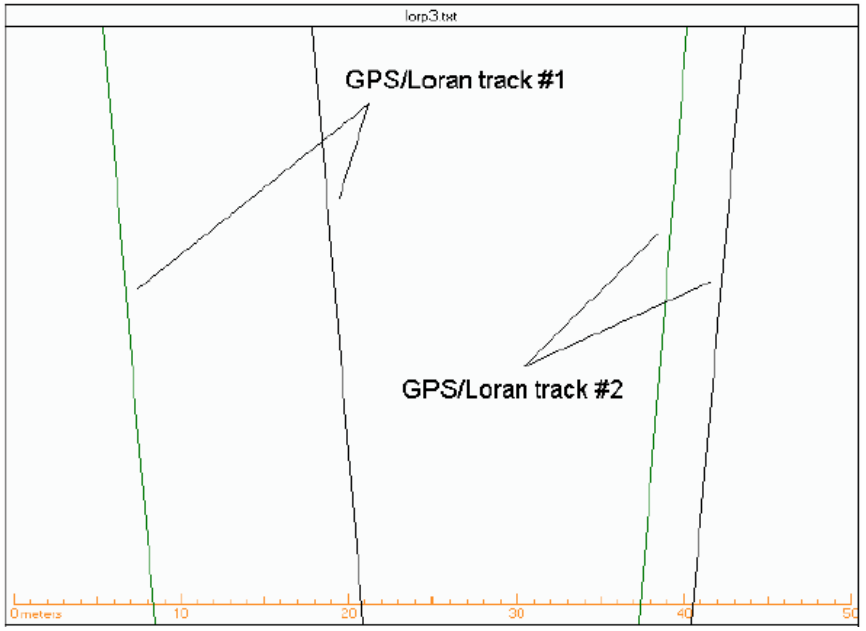


- Waco, TX flight tests December 2, 2003
- ASF corrections from October 17, 2003

FreeFlight/Locus GPS/Loran Integration Program - Initial Flight Tests



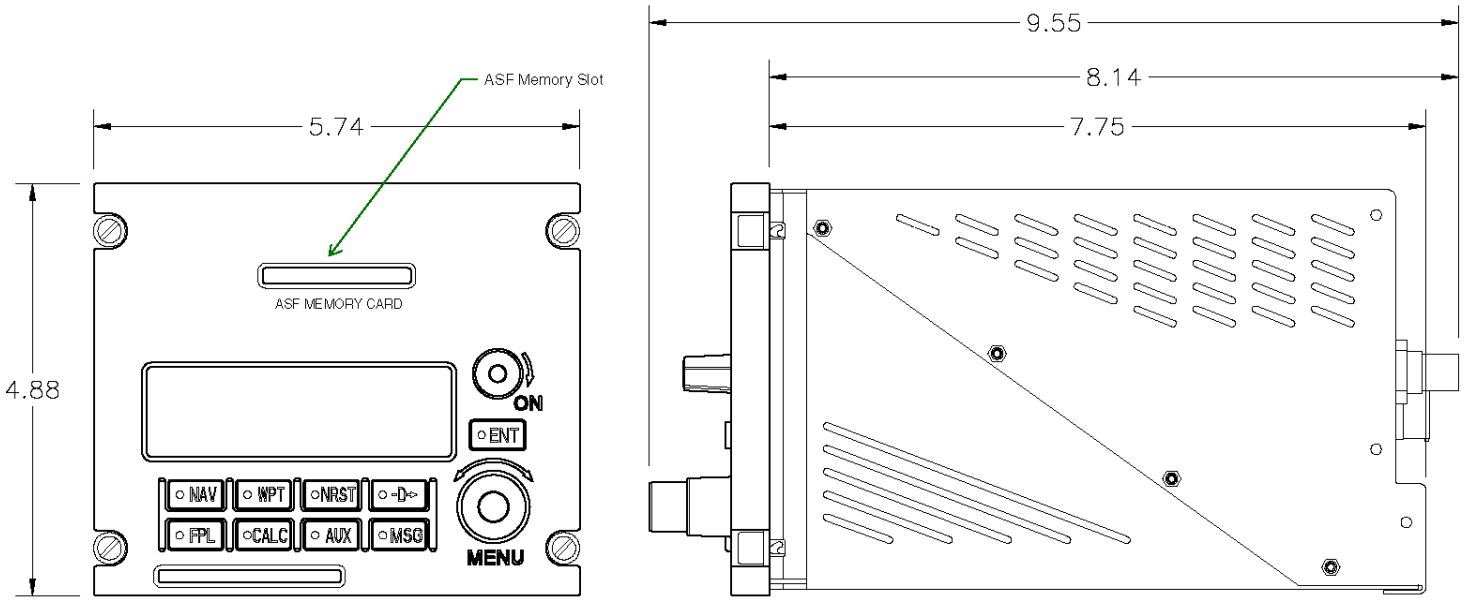
- tracks ~12 km from airport



- tracks ~ 6 km from airport

FreeFlight/Locus GPS/Loran Integration Program - Current Work

- Loran received to be integrated within 2101 enclosure using custom interface/power supply board
- Loran receiver to incorporate ASF flash card and apply ASFs in real time
- 2101 to integrate GPS and Loran position and integrity data, including the simulated loss of WAAS, GPS RAIM, and GPS
- Loran H-field antenna incorporates single axis gyro (SAG)



Combined GPS/LORAN Prototype w / ASF Memory Card

Summary

- Loran appears to be an excellent candidate to complement GPS in multimodal applications.
- Two programs have been conducted to evaluate aviation performance of integrated GPS/Loran prototype units.
- Rockwell Collins/Locus MMR prototype included various levels of GPS/Loran integration and flight tests demonstrated results well within RNP 0.3 requirements, plus enhanced integrity, availability, and continuity.
- Rockwell has continued work by integrating an IMU sensor, and initial tests have demonstrated high accuracy, low noise results.
- FreeFlight/Locus 2nd iteration prototype development is underway, and will include tighter GPS/Loran integration and SAG sensor in Loran unit.
- FreeFlight/Locus flight tests on 1st iteration prototype demonstrated promising results, well within FAA's RNP 0.3 requirements.
- The DOT has indicated it is planning to issue a long term Loran policy decision on June 30, 2004.